

SEMICONDUCTOR COMPONENT AND METHOD OF MANUFACTURING

Background of the Invention

5 **[0001]** This invention relates in general to electronics and, more particularly, to semiconductor components and methods of manufacturing.

10 **[0002]** Semiconductor components such as, for example, power transistors are used in a wide variety of applications, including telecommunication, computing, and automotive applications. A power transistor typically has a drain electrode located at a bottom side of the power transistor and also has a gate electrode and a source electrode at a top side of the power transistor. This configuration provides the power transistor with a vertical structure. A common problem with this type of power transistor, however, is its high drain-to-source on-resistance.

15 **[0003]** To reduce the drain-to-source on-resistance, a deep trench super junction has been added to this type of power transistor. The use of a deep trench super junction reduces an electric field intensity within the power transistor to permit the use of a higher doping level within a body of the power transistor. The higher doping level 20 reduces the drain-to-source on-resistance of the power transistor.

25 **[0004]** One problem with the use of a deep trench super junction in this type of power transistor is the creation of a Junction Field Effect Transistor (JFET) resistance within the power transistor. This JFET resistance is located below 30 the gate region. Another problem with the use of a deep trench super junction in this type of power transistor is the limitation of the minimum size or pitch of the power transistor. The minimum size of the power transistor is

determined by the diffusion of the dopant from the super junction. If the size of the power transistor is too small, the super junction will completely and permanently pinch-off the JFET region of the power transistor, and the power 5 transistor will not function properly. The size or pitch limitation limits the reduction of the power transistor's on-resistance.

10 [0005] Hence, there is a need for a semiconductor component having a low drain-to-source on-resistance, a small size, and a minimal JFET resistance. A need also exists for a method of manufacturing this semiconductor component.

Brief Description of the Drawings

15 [0006] The invention will be better understood from a reading of the following detailed description, taken in conjunction with the accompanying drawing figures in which:

20 FIG. 1 illustrates a cross-sectional view of a portion of a semiconductor component in accordance with an embodiment of the invention;

25 FIG. 2 illustrates a cross-sectional view of the portion of the semiconductor component after subsequent manufacturing steps in accordance with an embodiment of the invention;

FIG. 3 illustrates a cross-sectional view of the portion of the semiconductor component after further manufacturing steps in accordance with an embodiment of the invention;

30 FIG. 4 illustrates a cross-sectional view of the portion of the semiconductor component after still further manufacturing steps in accordance with an embodiment of the invention;

FIG. 5 illustrates a cross-sectional view of the

portion of the semiconductor component after yet further manufacturing steps in accordance with an embodiment of the invention;

5 FIG. 6 illustrates a cross-sectional view of the portion of the semiconductor component after additional manufacturing steps in accordance with an embodiment of the invention;

10 FIG. 7 illustrates a cross-sectional view of the portion of the semiconductor component after subsequent manufacturing steps in accordance with an embodiment of the invention;

15 FIG. 8 illustrates a cross-sectional view of the portion of the semiconductor component after further manufacturing steps in accordance with an embodiment of the invention;

FIG. 9 illustrates a cross-sectional view of the portion of the semiconductor component after still further manufacturing steps in accordance with an embodiment of the invention;

20 FIG. 10 illustrates a cross-sectional view of a portion of a different semiconductor component in accordance with an embodiment of the invention;

25 FIG. 11 illustrates a cross-sectional view of a portion of another semiconductor component in accordance with an embodiment of the invention;

FIG. 12 illustrates a cross-sectional view of a portion of yet another semiconductor component in accordance with an embodiment of the invention; and

30 FIG. 13 illustrates a flow chart of a method of manufacturing a semiconductor component in accordance with an embodiment of the invention.

[0007] For simplicity and clarity of illustration, the drawing figures illustrate the general manner of construction, and descriptions and details of well-known

features and techniques are omitted to avoid unnecessarily obscuring the invention. Additionally, elements in the drawing figures are not necessarily drawn to scale, and the same reference numerals in different figures denote the same elements.

[0008] Furthermore, the terms first, second, third, and the like in the description and in the claims, if any, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is further understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

[0009] Moreover, the terms top, bottom, over, under, and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing relative positions. It is understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other orientations than described or illustrated herein.

Detailed Description of the Drawings

[0010] In the preferred embodiment, a semiconductor component comprises at least a power transistor having a vertical structure. Further in the preferred embodiment, the power transistor is a Metal Oxide-Semiconductor FET (MOSFET). In other embodiments, the power transistor can be other types of FETs.

[0011] More particularly, the semiconductor component comprises a semiconductor layer having a trench. The trench has two sides opposite each other. A portion of the

semiconductor layer has a conductivity type and a charge density or doping concentration. The semiconductor component also comprises a control electrode in the trench and additionally comprises a channel region in the

5 semiconductor layer and adjacent to the trench. The semiconductor component still further comprises a region in the semiconductor layer where the region has a conductivity type different from the conductivity type of the portion of the semiconductor layer. The region in the semiconductor

10 layer also has a charge density that balances the charge density of the portion of the semiconductor layer.

[0012] Computer simulations have shown this power transistor to have, among other advantages, a reduction in drain-to-source on-resistance of approximately thirty percent compared to the drain-to-source on-resistances of previous power transistors having similar power ratings. Computer simulations have also shown this power transistor to have, among still other advantages, a reduction in size of up to fifty percent compared to the sizes of previous power transistors having similar power ratings.

[0013] The semiconductor component can be a discrete device or an integrated circuit. If the semiconductor component is a discrete device, the semiconductor component consists solely of a single power transistor. If the semiconductor component is an integrated circuit, the semiconductor component can comprise a single power transistor or a plurality of power transistors and can further comprise other types of transistors, resistors, and other types of devices within integrated circuits.

[0014] FIG. 1 illustrates a cross-sectional view of a semiconductor component 100. Semiconductor component 100 comprises a semiconductor layer 110. Semiconductor layer 110 can be comprised of a variety of semiconductor materials including, for example, silicon, germanium, silicon

germanium, or gallium arsenide. Semiconductor layer 110 can have a crystalline or epitaxial structure.

[0015] Semiconductor layer 110 has a surface 111 and a surface 112, which is opposite surface 111. At least a portion of semiconductor layer 110 has a conductivity type and a charge density. In the preferred embodiment, the conductivity type of semiconductor layer 110 is n-type, but in a different embodiment, the conductivity type of semiconductor layer 110 can be p-type. Also in the preferred embodiment, semiconductor layer 110 is deposited, grown, or otherwise formed with the conductivity type and the charge density, but in a different embodiment, semiconductor layer 110 can be doped to have the conductivity type and the charge density after semiconductor layer 110 is formed.

[0016] Semiconductor component 100 also comprises a channel region 120. Channel region 120 is formed in semiconductor layer 110. Channel region 120 has a different conductivity type than the portion of semiconductor layer 110. In the preferred embodiment, the conductivity type of channel region 120 is p-type. In a different embodiment where the conductivity type of the portion of semiconductor layer 110 is p-type, the conductivity type of channel region 120 can be n-type.

[0017] Semiconductor component 100 further comprises a semiconductor substrate 105. Semiconductor substrate 105 is underneath semiconductor layer 110. In particular, semiconductor substrate 105 is contiguous with surface 112 of semiconductor layer 110.

[0018] Semiconductor substrate 105 serves as a portion of a drain region for the power transistor in semiconductor component 100. Semiconductor substrate 105 has the same conductivity type as semiconductor layer 110. Semiconductor substrate 105 has a charge density that is greater than the

charge density of semiconductor layer 110 and channel region 120. As an example, semiconductor layer 110 can be epitaxially grown over semiconductor substrate 105.

[0019] Semiconductor component 100 still further comprises electrically insulative layers 116 and 117. As an example, electrically insulative layers 116 and 117 can be comprised of silicon dioxide, silicon nitride, silicon oxy-nitride, Tetra-Ethyl-Ortho-Silicate (TEOS), or Spin-On-Glass (SOG). In the preferred embodiment, electrically insulative layers 116 and 117 are both comprised of silicon dioxide.

[0020] Also in the preferred embodiment, electrically insulative layers 116 and 117 are formed over surface 111 of semiconductor layer 110 before channel region 120 is formed in semiconductor layer 110. In a different embodiment, electrically insulative layers 116 and 117 can be eliminated from semiconductor component 100. In a further embodiment, electrically insulative layer 116 can be eliminated from semiconductor component 100 while electrically insulative layer 117 remains in semiconductor component 100.

[0021] When electrically insulative layers 116 and 117 are present in semiconductor component 100, electrically insulative layer 116 is formed over surface 111 of semiconductor layer 110. Then, electrically insulative layer 116 is etched to expose a portion of surface 111 of semiconductor layer 110. Next, electrically insulative layer 117 is formed over the exposed portion of surface 111 of semiconductor layer 110. As an example, electrically insulative layer 117 can be formed by thermally oxidizing the exposed portion of surface 111 of semiconductor layer 110 to a thickness of approximately twenty to fifty nanometers.

[0022] After the formation of electrically insulative layer 117, a dopant is implanted through electrically insulative layer 117 and into surface 111 of semiconductor

0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

layer 110 to form channel region 120. In this embodiment, electrically insulative layer 117 serves as an implant screen. The implantation of channel region 120 can occur with or without an implant mask. As an example, an implant 5 dose of approximately 1×10^{13} to 1×10^{14} atoms per centimeter squared can be used to form channel region 120.

[0023] After the implantation of channel region 120, a high temperature step is used to activate the implanted dopant used to form channel region 120. As an example, a 10 temperature of approximately 1000 to 1250 degrees Celsius can be used.

[0024] FIG. 2 illustrates a cross-sectional view of the portion of semiconductor component 100 after subsequent manufacturing steps. An electrically insulative layer 225 is formed over electrically insulative layers 116 and 117. As an example, electrically insulative layer 225 can be comprised of silicon dioxide, silicon nitride, silicon oxy-nitrite, TEOS, or SOG. In the preferred embodiment, electrically insulative layer 225 is comprised of silicon 15 nitride.

[0025] A hole 226 is etched into electrically insulative layers 225 and 117. Hole 226 exposes a portion of surface 111 of semiconductor layer 110. Hole 226 is located over channel region 120.

[0026] FIG. 3 illustrates a cross-sectional view of the portion of semiconductor component 100 after further manufacturing steps. A trench 326 is etched into surface 111 of semiconductor layer 110. As an example, trench 326 can have a depth of approximately one to one-and-a-half 20 microns and a width of less than one micron.

[0027] Trench 326 has two sides, each of which is adjacent to, and preferably contiguous with, a different portion of channel region 120. In the preferred embodiment, the side walls of trench 326 located at the sides of trench

326 are perpendicular to surface 111 of semiconductor layer 110. Channel region 120 circumscribes trench 326. Trench 326 can extend into semiconductor layer 110 deeper than channel region 120. In this preferred embodiment, channel 5 region 120 is absent underneath trench 326. Accordingly, the power transistor in semiconductor component 100 preferably has a vertical channel length that is perpendicular to surface 111 of semiconductor layer 110.

[0028] Hole 226 (FIG. 2) in electrically insulative 10 layers 225 (FIG. 2) and 117 is used to define trench 326 in semiconductor layer 110. As an example, a Reactive Ion Etch (RIE) process can be used to form trench 326 in semiconductor layer 110 without using a photoresist etch mask. This RIE process can form trench 326 with rounded or 15 non-rounded corners at the bottom of trench 326.

[0029] After the formation of trench 326, electrically insulative layer 225 (FIG. 2) is removed. Before the removal of electrically insulative layer 225 (FIG. 2), a 20 sacrificial oxide layer can be thermally grown along the side walls of trench 326 to protect trench 326 during the removal of electrically insulative layer 225 (FIG. 2). After the removal of electrically insulative layer 225 (FIG. 2), the sacrificial oxide layer can also be removed.

[0030] In a different embodiment, electrically insulative 25 layer 225 (FIG. 2) can be eliminated from semiconductor component 100. In this embodiment, an etch mask comprised of photoresist can be used to define trench 326 in semiconductor layer 110.

[0031] FIG. 4 illustrates a cross-sectional view of the 30 portion of semiconductor component 100 after still further manufacturing steps. An electrically insulative layer 430 is formed in trench 326. When the power transistor of semiconductor component 100 is a MOSFET, electrically insulative layer 430 serves as a gate dielectric layer. If

the power transistor in semiconductor component 100 is a Metal-Semiconductor FET (MESFET), electrically insulative layer 430 is not present in trench 326.

[0032] As an example, electrically insulative layer 430

5 can be comprised of silicon dioxide, silicon nitride, silicon oxy-nitride, TEOS, or SOG. In the preferred embodiment, electrically insulative layer 430 is comprised of silicon dioxide. Also in the preferred embodiment, electrically insulative layer 430 is thermally grown along 10 the side walls of trench 326. Any portions of semiconductor layer 110 forming the side walls of trench 326 that were damaged during the formation of trench 326 or thereafter may need to be removed prior to forming electrically insulative layer 430.

15 **[0033]** Next, an electrically conductive layer 435 is formed in trench 326 and over electrically insulative layers 116, 117, and 430. In the preferred embodiment, electrically conductive layer 435 is deposited to be electrically conductive. In a different embodiment, electrically conductive layer 435 is first deposited and 20 subsequently doped to be electrically conductive.

[0034] As an example, electrically conductive layer 435 can be comprised of doped polycrystalline silicon (polysilicon) or a metal such as, for example, titanium,

25 tungsten, or titanium tungsten. In the embodiment where the power transistor in semiconductor component 100 is a MOSFET, electrically conductive layer 435 can be comprised of in-situ phosphorous-doped polysilicon.

[0035] FIG. 5 illustrates a cross-sectional view of the

30 portion of semiconductor component 100 after yet further manufacturing steps. Electrically conductive layer 435 (FIG. 4) is etched to form a control electrode 540 within trench 326. Electrically insulative layer 430 is located between control electrode 540 and semiconductor layer 110.

Control electrode 540 is located adjacent to channel region 120, which circumscribes control electrode 540.

Furthermore, control electrode is located preferably only within trench 326 and does not extend out of trench 326.

5 [0036] FIG. 6 illustrates a cross-sectional view of the portion of semiconductor component 100 after additional manufacturing steps. A trench 645 is formed in semiconductor layer 110. Trench 645 is first etched through electrically insulative layer 116 (FIG. 5) before being etched into surface 111 of semiconductor layer 110. In the preferred embodiment, trench 645 surrounds the power transistor of semiconductor component 100. As an example, trench 645 can be approximately forty to seventy micrometers deep and approximately two to five micrometers wide.

10 [0037] Trench 645 extends deeper into semiconductor layer 110 from surface 111 of semiconductor layer 110 than trench 326. In the preferred embodiment, trench 645 extends from surface 111 of semiconductor layer 110 to surface 112 of semiconductor layer 110. Furthermore, in the preferred embodiment, trench 645 extends into semiconductor substrate 105. In a different embodiment, trench 645 can be devoid of extending into semiconductor substrate 105. In another embodiment, trench 645 can be devoid of extending to surface 112 of semiconductor layer 110.

15 [0038] FIG. 7 illustrates a cross-sectional view of the portion of semiconductor component 100 after subsequent manufacturing steps. A layer 750 is formed, among other places, along the side walls of trench 645. Layer 750 is doped and has the same conductivity type as channel region 120.

20 [0039] As an example, layer 750 can be comprised of in-situ boron-doped polysilicon or SOG. In another embodiment, layer 750 can be comprised of boron nitride doped with a plasma immersion technique.

[0040] In yet another embodiment, layer 750 can be replaced by an epitaxial layer grown along the side walls of trench 645 using a reduced-pressure epitaxial reactor. In this embodiment, the epitaxial layer has a different configuration than illustrated in FIG. 7. In particular, the epitaxial layer can be grown only at exposed portions of semiconductor layer 110. Accordingly, the epitaxial layer would not be formed over electrically insulative layers 117 or 430. As an example, the epitaxial layer can be comprised of silicon, which can be doped in-situ or after being grown.

[0041] After the formation of layer 750, semiconductor component 100 is annealed to drive the dopant within layer 750 into semiconductor layer 110. The dopant forms a region 755 in semiconductor layer 110. This annealing process can occur in an inert ambient at approximately 950 to 1050 degrees Celsius.

[0042] When layer 750 is comprised of silicon, this annealing process also converts layer 750 into silicon dioxide. This conversion process prevents the formation of a leaky junction along the side walls of trench 645. This conversion process also eliminates any electrically conductive regions over electrically insulative layers 117 and 430.

[0043] Region 755 is located adjacent to trench 326. Region 755 has portions 756 and 757. Trench 645 is contiguous with each of portions 756 and 757 of region 755.

[0044] Portion 756 of region 755 is at one side of trench 326 and extends along a height of semiconductor layer 110 from surface 112 of semiconductor layer 110 toward surface 111 of semiconductor layer 110. Portion 757 of region 755 is at an opposite side of trench 326 and extends along the height of semiconductor layer 110 from surface 112 of semiconductor layer 110 toward surface 111 of semiconductor layer 110.

[0045] In the preferred embodiment, region 755 is continuous. In particular, region 755 extends continuously along the height of semiconductor layer 110 from surface 112 of semiconductor layer 110 toward surface 111 of semiconductor layer 110. More particularly, each of portions 756 and 757 of region 755 are continuous from surface 112 of semiconductor layer 110 toward surface 111 of semiconductor layer 110. Further in the preferred embodiment, portions 756 and 757 are contiguous with each other such that all of region 755 is continuous. In a different embodiment, region 755 may be comprised of a plurality of separate or discontinuous regions.

[0046] As illustrated in FIG. 7, region 755 is contiguous with surface 112 of semiconductor layer 110. Depending on the doping concentration of region 755, as explained in more detail hereinafter, region 755 may or may not be contiguous with surface 111 of semiconductor layer 110.

[0047] A portion 713 of semiconductor layer 110 is located between portions 756 and 757 of region 755. Portion 713 of semiconductor layer 110 is also located under trench 326. Portion 713 serves as another portion of the drain region for the power transistor in semiconductor component 100. Portion 713 has the conductivity type and the charge density of semiconductor layer 110. Portions 756 and 757 of region 755 extend from the side walls of trench 645 toward the center of portion 713, but preferably do not extend underneath trench 645.

[0048] Region 755 has the same conductivity type as channel region 120. Region 755 also has a charge density. The charge density of region 755 balances the charge density of portion 713 of semiconductor layer 110. The charge densities of region 755 and of portion 713 of semiconductor layer 110 are each less than the charge density of semiconductor substrate 105.

[0049] If the power transistor in semiconductor component 100 has a lower power rating in the range of approximately one hundred volts, then region 755 has a lower charge density. If, however, the power transistor has a higher power rating in the range of approximately four hundred to one thousand two hundred volts, then region 755 has a higher charged density. As an example, the charge density of region 755 can be approximately 5×10^{12} to 1×10^{17} atoms per centimeter cubed.

[0050] Another factor affecting the charge density of region 755 is the relative size or volume of region 755. The charge density of region 755 can be equal to the charge density of portion 713 of semiconductor layer 110 when region 755 and portion 713 have equal volumes. Similarly, the charge density of region 755 can be greater than the charge density of portion 713 when region 755 has a smaller volume than portion 713, and region 755 can have a lower charge density than portion 713 when region 755 has a larger volume than portion 713.

[0051] When the charge density of region 755 is greater than the charge density of portion 713, region 755 can extend completely from surface 112 of semiconductor layer 110 to surface 111 of semiconductor layer 110. In this embodiment, region 755 is contiguous with surfaces 111 and 112 of semiconductor layer 110. Also in this embodiment, channel region 120 is located between portions 756 and 757 of region 755.

[0052] FIG. 8 illustrates a cross-sectional view of the portion of semiconductor component 100 after further manufacturing steps. A region 860 is formed in semiconductor layer 110 at surface 111 of semiconductor layer 110. In the preferred embodiment, region 860 completely encircles control electrode 540, but in a different embodiment, region 860 only partially encircles

control electrode 540. Region 860 has the same conductivity type as portion 713 of semiconductor layer 110 and is contiguous with trench 326.

[0053] Region 860 serves as a source region for the power transistor in semiconductor component 100. Accordingly, the charge density within region 860 is greater than the charge density in channel region 120, portion 713 of semiconductor layer 110, and region 755.

[0054] As an example, region 860 can be implanted through layers 750 and 117 into surface 111 of semiconductor layer 110. In the preferred embodiment, the implantation process is performed at a zero degree angle, which is substantially perpendicular to surface 111 of semiconductor layer 110. This implantation process can be performed with or without an implant mask.

[0055] Next, trench 645 is filled with an electrically insulative layer 865. As an example, electrically insulative layer 865 can be comprised of undoped polysilicon, silicon dioxide, silicon nitride, silicon oxy-nitride, TEOS, or SOG. In the preferred embodiment, electrically insulative layer 865 is comprised of an electrically insulative material, such as TEOS, that can be deposited at a lower temperature. The lower temperature deposition process does not stress the regions and layers adjacent to trench 645. Electrically insulative layer 865 can be planarized.

[0056] FIG. 9 illustrates a cross-sectional view of the portion of semiconductor component 100 after still further manufacturing steps. Electrically insulative layer 865 (FIG. 8) is etched to leave a portion 966 within trench 645 and a portion 967 over control electrode 540. This etch process also removes portions of layers 750 and 117 to expose portions of region 860 in semiconductor layer 110.

[0057] Next, an electrical contact 970 can be formed to

contact doped region 860. Electrical contact 970 serves as a source electrode for the power transistor in semiconductor component 100. Semiconductor component 100 also comprises a drain electrode (not shown in FIG. 9) coupled to 5 semiconductor substrate 105. Semiconductor substrate 105 can be thinned before forming the drain electrode.

[0058] FIG. 10 illustrates a cross-sectional view of a portion of a semiconductor component 1000. Semiconductor component 1000 in FIG. 10 is a different embodiment of 10 semiconductor component 100 (FIG. 9) during an intermediate stage of manufacturing. In particular, semiconductor component 1000 is illustrated in FIG. 10 after a manufacturing step occurring between the completed manufacturing steps illustrated in FIGS. 7 and 8 of semiconductor component 100. More specifically, 15 semiconductor component 1000 in FIG. 10 is illustrated after formation of a region 1060 in semiconductor layer 110.

[0059] Region 1060 in FIG. 10 is similar to region 860 (FIG. 8) in semiconductor component 100 (FIG. 8).

20 Accordingly, region 1060 serves as a source region for the power transistor in semiconductor component 1000.

[0060] Region 755 is formed in semiconductor layer 110 before region 1060 is formed in semiconductor layer 110. After the formation of region 755, an implant mask 1075 is 25 formed, as illustrated in FIG. 10. Implant mask 1075 is used to define the location and/or configuration of region 1060 within semiconductor layer 110. As an example, implant mask 1075 can be comprised of photoresist. Similar to region 860 in FIG. 8, region 1060 in FIG. 10 can be formed 30 by an ion implantation process.

[0061] The location and/or configuration of region 1060, as illustrated in FIG. 10, improves the electrical performance of the power transistor in semiconductor component 1000. After the formation of region 1060, implant

0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
2210
2211
2212
2213
2214
2215
2216
2217
2218
2219
2220
2221
2222
2223
2224
2225
2226
2227
2228
2229
2230
2231
2232
2233
2234
2235
2236
2237
2238
2239
22310
22311
22312
22313
22314
22315
22316
22317
22318
22319
22320
22321
22322
22323
22324
22325
22326
22327
22328
22329
22330
22331
22332
22333
22334
22335
22336
22337
22338
22339
22340
22341
22342
22343
22344
22345
22346
22347
22348
22349
22350
22351
22352
22353
22354
22355
22356
22357
22358
22359
22360
22361
22362
22363
22364
22365
22366
22367
22368
22369
22370
22371
22372
22373
22374
22375
22376
22377
22378
22379
22380
22381
22382
22383
22384
22385
22386
22387
22388
22389
22390
22391
22392
22393
22394
22395
22396
22397
22398
22399
223100
223101
223102
223103
223104
223105
223106
223107
223108
223109
223110
223111
223112
223113
223114
223115
223116
223117
223118
223119
223120
223121
223122
223123
223124
223125
223126
223127
223128
223129
223130
223131
223132
223133
223134
223135
223136
223137
223138
223139
223140
223141
223142
223143
223144
223145
223146
223147
223148
223149
223150
223151
223152
223153
223154
223155
223156
223157
223158
223159
223160
223161
223162
223163
223164
223165
223166
223167
223168
223169
223170
223171
223172
223173
223174
223175
223176
223177
223178
223179
223180
223181
223182
223183
223184
223185
223186
223187
223188
223189
223190
223191
223192
223193
223194
223195
223196
223197
223198
223199
223200
223201
223202
223203
223204
223205
223206
223207
223208
223209
223210
223211
223212
223213
223214
223215
223216
223217
223218
223219
223220
223221
223222
223223
223224
223225
223226
223227
223228
223229
223230
223231
223232
223233
223234
223235
223236
223237
223238
223239
223240
223241
223242
223243
223244
223245
223246
223247
223248
223249
223250
223251
223252
223253
223254
223255
223256
223257
223258
223259
223260
223261
223262
223263
223264
223265
223266
223267
223268
223269
223270
223271
223272
223273
223274
223275
223276
223277
223278
223279
223280
223281
223282
223283
223284
223285
223286
223287
223288
223289
223290
223291
223292
223293
223294
223295
223296
223297
223298
223299
223300
223301
223302
223303
223304
223305
223306
223307
223308
223309
223310
223311
223312
223313
223314
223315
223316
223317
223318
223319
223320
223321
223322
223323
223324
223325
223326
223327
223328
223329
223330
223331
223332
223333
223334
223335
223336
223337
223338
223339
223340
223341
223342
223343
223344
223345
223346
223347
223348
223349
223350
223351
223352
223353
223354
223355
223356
223357
223358
223359
223360
223361
223362
223363
223364
223365
223366
223367
223368
223369
223370
223371
223372
223373
223374
223375
223376
223377
223378
223379
223380
223381
223382
223383
223384
223385
223386
223387
223388
223389
223390
223391
223392
223393
223394
223395
223396
223397
223398
223399
223400
223401
223402
223403
223404
223405
223406
223407
223408
223409
223410
223411
223412
223413
223414
223415
223416
223417
223418
223419
223420
223421
223422
223423
223424
223425
223426
223427
223428
223429
223430
223431
223432
223433
223434
223435
223436
223437
223438
223439
223440
223441
223442
223443
223444
223445
223446
223447
223448
223449
223450
223451
223452
223453
223454
223455
223456
223457
223458
223459
223460
223461
223462
223463
223464
223465
223466
223467
223468
223469
223470
223471
223472
223473
223474
223475
223476
223477
223478
223479
223480
223481
223482
223483
223484
223485
223486
223487
223488
223489
223490
223491
223492
223493
223494
223495
223496
223497
223498
223499
223500
223501
223502
223503
223504
223505
223506
223507
223508
223509
223510
223511
223512
223513
223514
223515
223516
223517
223518
223519
223520
223521
223522
223523
223524
223525
223526
223527
223528
223529
223530
223531
223532
223533
223534
223535
223536
223537
223538
223539
223540
223541
223542
223543
223544
223545
223546
223547
223548
223549
223550
223551
223552
223553
223554
223555
223556
223557
223558
223559
223560
223561
223562
223563
223564
223565
223566
223567
223568
223569
223570
223571
223572
223573
223574
223575
223576
223577
223578
223579
223580
223581
223582
223583
223584
223585
223586
223587
223588
223589
223590
223591
223592
223593
223594
223595
223596
223597
223598
223599
223600
223601
223602
223603
223604
223605
223606
223607
223608
223609
223610
223611
223612
223613
223614
223615
223616
223617
223618
223619
223620
223621
223622
223623
223624
223625
223626
223627
223628
223629
223630
223631
223632
223633
223634
223635
223636
223637
223638
223639
223640
223641
223642
223643
223644
223645
223646
223647
223648
223649
223650
223651
223652
223653
223654
223655
223656
223657
223658
223659
223660
223661
223662
223663
223664
223665
223666
223667
223668
223669
223670
223671
223672
223673
223674
223675
223676
223677
223678
223679
223680
223681
223682
223683
223684
223685
223686
223687
223688
223689
223690
223691
223692
223693
223694
223695
223696
223697
223698
223699
223700
223701
223702
223703
223704
223705
223706
223707
223708
223709
223710
223711
223712
223713
223714
223715
223716
223717
223718
223719
223720
223721
223722
223723
223724
223725
223726
223727
223728
223729
223730
223731
223732
223733
223734
223735
223736
223737
223738
223739
223740
223741
223742
223743
223744
223745
223746
223747
223748
223749
223750
223751
223752
223753
223754
223755
223756
223757
223758
223759
223760
223761
223762
223763
223764
223765
223766
223767
223768
223769
223770
223771
223772
223773
223774
223775
223776
223777
223778
223779
223780
223781
223782
223783
223784
223785
223786
223787
223788
223789
223790
223791
223792
223793
223794
223795
223796
223797
223798
223799
223800
223801
223802
223803
223804
223805
223806
223807
223808
223809
223810
223811
223812
223813
223814
223815
223816
223817
223818
223819
223820
223821
223822
223823
223824
223825
223826
223827
223828
223829
223830
223831
223832
223833
223834
223835
223836
223837
223838
223839
223840
223841
223842
223843
223844
223845
223846
223847
223848
223849
223850
223851
223852
223853
223854
223855
223856
223857
223858
223859
223860
223861
223862
223863
223864
223865
223866
223867
223868
223869
223870
223871
223872
223873
223874
223875
223876
223877
223878
223879
223880
223881
223882
223883
223884
223885
223886
223887
223888
223889
223890
223891
223892
223893
223894
223895
223896
223897
223898
223899
223900
223901
223902
223903
223904
223905
223906
223907
223908
223909
223910
223911
223912
223913
223914
223915
223916
223917
223918
223919
223920
223921
223922
223923
223924
223925
223926
223927
223928
223929
223930
223931
223932
223933
223934
223935
223936
223937
223938
223939
223940
223941
223942
223943
223944
223945
223946
223947
223948
223949
223950
223951
223952
223953
223954
223955
223956
223957
223958
223959
223960
223961
223962
223963
223964
223965
223966
223967
223968
223969
223970
223971
223972
223973
223974
223975
223976
223977
223978
223979
223980
223981
223982
223983
223984
223985
223986
223987
223988
223989
223990
223991
223992
223993
223994
223995
223996
223997
223998
223999
2239999

mask 1075 is removed, and electrically insulative layer 865 (FIG. 8) is formed. With the exception of region 1060 in semiconductor component 1000 and region 860 (FIG. 8) in semiconductor component 100 (FIG. 8), semiconductor

5 components 100 and 1000 can be identical with each other.

[0062] FIG. 11 illustrates a cross-sectional view of a portion of a semiconductor component 1100. Semiconductor component 1100 in FIG. 11 is a different embodiment of semiconductor component 100 (FIG. 9) during an intermediate 10 stage of manufacturing. In particular, semiconductor component 1100 is illustrated in FIG. 11 after a manufacturing step occurring between the completed manufacturing steps illustrated in FIGS. 8 and 9 of semiconductor component 100. More specifically, semiconductor component 1100 in FIG. 11 is illustrated after a modification of the source region of the power transistor in semiconductor component 1100.

[0063] After the formation of region 860 (FIG. 8) in semiconductor layer 110 and after the patterning of electrically insulative layer 865 (FIG. 8) into portions 966 and 967, an implant mask 1180 is formed, as illustrated in FIG. 11. As an example, implant mask 1180 can be comprised of photoresist. Implant mask 1180 is used to define the location and/or configuration of an implanted region in 20 semiconductor layer 110.

[0064] The implanted region converts a portion of region 860 (FIG. 8) back to channel region 120. Accordingly, the implanted region changes the shape and/or configuration of region 860 (FIG. 8) to a region 1160. In a different 30 embodiment, the implanted region can convert a portion of region 860 (FIG. 8) back to region 755.

[0065] The location and/or configuration of region 1160, as illustrated in FIG. 11, improves the electrical performance of the power transistor in semiconductor

component 1100. After the formation of region 1160, implant mask 1180 is removed, and electrical contact 970 (FIG. 9) is formed.

[0066] Semiconductor component 1100 in FIG. 11 can also have another difference from semiconductor component 100 in FIG. 7. In particular, layer 750 of semiconductor component 100 in FIG. 7 is changed to an epitaxial layer that is formed only on the exposed portions of semiconductor layer 110. This epitaxial layer is represented in FIG. 11 by a layer 1150. Layer 1150 is not formed over electrically insulative layer 117. Layer 1150 may or may not be formed over control electrode 540. In FIG. 11, layer 1150 is not illustrated to be located over control electrode 540.

[0067] With the exception of region 1160 and layer 1150 in semiconductor component 1100 and region 860 and layer 750 in semiconductor component 100, semiconductor components 100 and 1100 can be identical with each other.

[0068] FIG. 12 illustrates a cross-sectional view of a portion of a semiconductor component 1200. Semiconductor component 1200 in FIG. 12 is a different embodiment of semiconductor component 100 in FIG. 9. Semiconductor component 1200 has a control electrode 1240. Control electrode 1240 of semiconductor component 1200 in FIG. 12 is different from control electrode 540 of semiconductor component 100 in FIG. 9. In particular, control electrode 1240 in FIG. 12 extends out of trench 326 and overlaps surface 111 of semiconductor layer 110 while control electrode 540 in FIG. 9 does not extend out of trench 326.

[0069] Control electrode 1240 changes the configuration of subsequently formed layer 750. Control electrode 1240 also changes the configuration of subsequently formed source region, or a region 1260, for the power transistor in semiconductor component 1200. Region 1260 in FIG. 12 is similar to region 860 in FIG. 9, but region 1260 in FIG. 12

is non-contiguous with trench 326. Control electrode 1240 further changes the configurations of subsequently formed portion 967 and electrical contact 970. Aside from these exceptions, semiconductor components 100 and 1200 can be 5 identical with each other.

[0070] FIG. 13 illustrates a flow chart 1300 of a method of manufacturing a semiconductor component. As an example, the semiconductor component of flow chart 1300 can be similar to semiconductor component 100 in FIG. 9, 10 semiconductor component 1000 in FIG. 10, semiconductor component 1100 in FIG. 11, or semiconductor component 1200 in FIG. 12.

[0071] At a step 1310 of flow chart 1300 in FIG. 13, a semiconductor layer is provided over a semiconductor substrate. As an example, the semiconductor layer and the semiconductor substrate of step 1310 in FIG. 13 can be similar to semiconductor layer 110 and semiconductor substrate 105, respectively, in FIG. 1.

[0072] Then, at a step 1320 of flow chart 1300 in FIG. 13, a channel region is formed in the semiconductor layer. As an example, the channel region of step 1320 in FIG. 13 can be similar to channel region 120 in FIG. 1.

[0073] Next, at a step 1330 of flow chart 1300 in FIG. 13, a trench is formed in the semiconductor layer. The 25 trench of step 1330 is a shallow trench. As an example, the trench of step 1330 in FIG. 13 can be similar to trench 326 in FIG. 3.

[0074] Subsequently, at a step 1340 of flow chart 1300 in FIG. 13, a control electrode is formed in the trench. As an 30 example, the control electrode of step 1340 can be similar to control electrode 540 in FIG. 5 or control electrode 1240 in FIG. 12.

[0075] Continuing with a step 1350 of flow chart 1300 in FIG. 13, another trench is formed in the semiconductor

20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1110
1111
1112
1113
1114
1115
1116
1117<br

layer. The trench of step 1350 is a deep trench. As an example, the trench of step 1350 in FIG. 13 can be similar to trench 645 in FIG. 6.

[0076] Then, at a step 1360 of flow chart 1300 in FIG. 13, a charge balancing region is formed in the semiconductor layer. As an example, the charge balancing region of step 1360 in FIG. 13 can be similar to region 755 in FIG. 7.

[0077] Next, at a step 1370 of flow chart 1300 in FIG. 13, a heavily doped region is formed in the semiconductor layer. As an example, the heavily doped region of step 1370 in FIG. 13 can be similar to region 860 in FIG. 8, region 1060 in FIG. 10, region 1160 in FIG. 11, or region 1260 in FIG. 12.

[0078] Subsequently, at a step 1380 of flow chart 1300 in FIG. 13, an electrical contact is formed to be coupled to the heavily doped region. As an example, the electrical contact of step 1380 in FIG. 13 can be similar to electrical contact 970 of FIG. 9.

[0079] Continuing with a step 1390 of flow chart 1300 in FIG. 13, another electrical contact is formed to be coupled to the semiconductor substrate. As an example, the electrical contact of step 1390 can be similar to the drain electrode described earlier with reference to FIG. 9.

[0080] In summary, an improved semiconductor component and method of manufacturing is provided to overcome the disadvantages of the prior art. The semiconductor component described herein has a shallow trench and a deep trench. The deep trench is used to form a super junction to lower the drain-to-source on-resistance of the power transistor in the semiconductor component. The shallow trench further lowers the drain-to-source on-resistance by eliminating, or at least reducing, the JFET resistance.

[0081] The use of the shallow trench also eliminates the minimum spacing requirement for the JFET region in the power

transistors of the prior technologies. With the use of the shallow trench, the minimum spacing requirement of the charge balancing region is controlled by lithographic and etching limitations, which can easily be controlled to 5 within the sub-micrometer range. Computer simulations have shown that, for an equal value of on-resistance, the power transistor of the semiconductor component described herein can have a fifty percent reduction in size compared to the power transistors of the prior technologies.

10 [0082] Although the invention has been described with reference to specific embodiments, those skilled in the art will understand that various changes may be made without departing from the spirit or scope of the invention. For instance, the numerous details set forth herein such as, for example, the compositions, locations, and configurations of the layers and regions are provided to facilitate the understanding of the invention and are not provided to limit the scope of the invention. As an additional example, other electrically conductive layers and/or electrically insulative layers can be added to the semiconductor components described herein. For instance, control electrode 540 in FIG. 9 can be comprised of a plurality of electrically conductive layers. Moreover, trench 645 in FIG. 9 can be filled with additional electrically insulative and/or conductive layers. 15 20 25

[0083] As another example, semiconductor substrate 105 can be eliminated from semiconductor component 100 in FIG. 9 such that a drain electrode can be connected directly to surface 112 of semiconductor layer 110. Furthermore, layer 30 750 in component 100 can be eliminated, and an ion implantation process and a diffusion process can be used to form region 755 directly in semiconductor layer 110. Moreover, the various concepts described earlier in this paragraph, in the preceding paragraph, in semiconductor

component 100 in FIGs. 1-9, in semiconductor component 1000 in FIG. 10, in semiconductor component 1100 in FIG. 11, and in semiconductor component 1200 in FIG. 12 can be selectively combined with each other.

5 **[0084]** Accordingly, the disclosure of embodiments of the invention is intended to be illustrative of the scope of the invention and is not intended to be limiting. It is intended that the scope of the invention shall be limited only to the extent required by the appended claims.

10

2022-02-07